PEREGRINE: THE MONTE CARLO METHOD

Summary

PEREGRINE is a 3D Monte Carlo dose calculation system designed specifically for radiation therapy planning. Unlike current dose calculation methods, which approximate dose distributions in the patient based on water phantom measurements, PEREGRINE determines the dose in the patient by simulating the actual treatment, particle interaction-by-particle interaction. PEREGRINE is designed to calculate dose distributions for photon, electron, fast neutron, and proton therapy.

The Monte Carlo Method

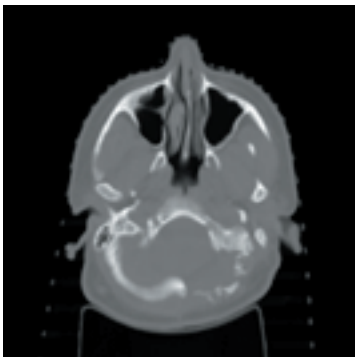
Physics When patients receive radiation therapy, they are bombarded by billions to trillions of particles. For example, a brain tumor patient treated with a 70 Gy midline dose has been irradiated with about 600 trillion incident particles during the course of his treatment.

PEREGRINE Monte Carlo transport algorithms determine the dose deposited in the patient by following the path of representative particles as they travel through the body. The probabilistic laws of modern physics prevent us from knowing the exact fate of *each* particle, but allow us to predict the distribution of how these particles, and their daughter products, interact in matter. By sampling *millions* of the *trillions* of particles that enter the body, and then recording the energy deposited by each as it travels through the body, the PEREGRINE All Particle Monte Carlo algorithms develops an accurate representation of the dose distribution.

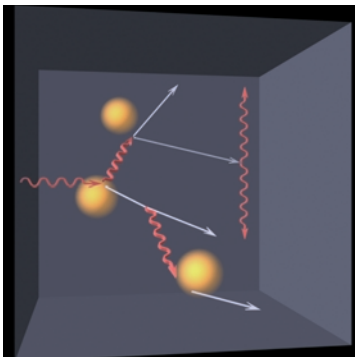
CT Scans The exact location of the tumor and sensitive structures and a map of the density and elemental composition of all matter in the vicinity of the beams are required to develop accurate patient-specific treatment plans. Using CT scans, PEREGRINE derives this information with both high accuracy and high spatial resolution. It utilizes this information to evaluate the detailed path-interaction physics required to ensure the accuracy of dose distribution throughout the treatment volume.

Databases The accuracy of Monte Carlo dose calculations depends on the availability of reliable, physically-consistent databases. Lawrence Livermore National Laboratory (LLNL) houses the world's most extensive nuclear and atomic cross section database, which parameterizes the interactions of photons, electrons/positrons, neutrons, protons, and other heavy charged particles. In addition, for the PEREGRINE project, LLNL has extended its databases to 250 MeV for biologically important elements for the specific purpose of calculating dose distributions for proton and fast neutron therapy. A key feature of the LLNL databases

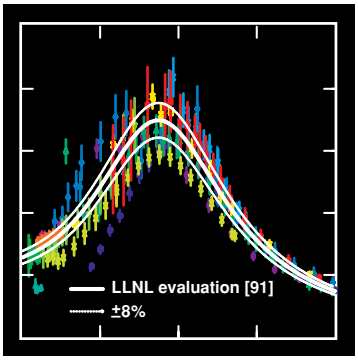
PEREGRINE: First-principles, Self-consistent 3D Monte Carlo Dose Calculations



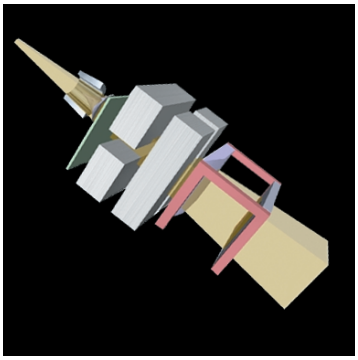
CT Scan-based Geometry



All Particle Monte Carlo Transport Physics



LLNL Fully-coupled Self-consistent Cross Section Databases



First-Principles Monte Carlo Source Model

PEREGRINE

is that they are the only fully-coupled and self-consistent compilations available. Because of this feature, PEREGRINE is able to calculate dose distributions resulting from any combination of photon, electron, neutron, or proton therapy in a single integrated transport package.

Sources Accurate Monte Carlo dose calculations rely on detailed understanding and modeling of the radiation source. PEREGRINE is the first dose algorithm to treat sources from first principles. The effects of patient-dependent beam modifiers such as collimators, apertures, blocks and wedges are modeled explicitly during each PEREGRINE calculation. Each accelerator is fully modeled to ensure accurate representation of the radiation source. Preliminary investigations of the impact of machine-to-machine variation on source characterization have indicated that a baseline Monte Carlo simulation of the manufacturer-specified beamlines and minimal optimization of parameters, results in excellent agreement of dose calculations with measurements.

Calculation Time

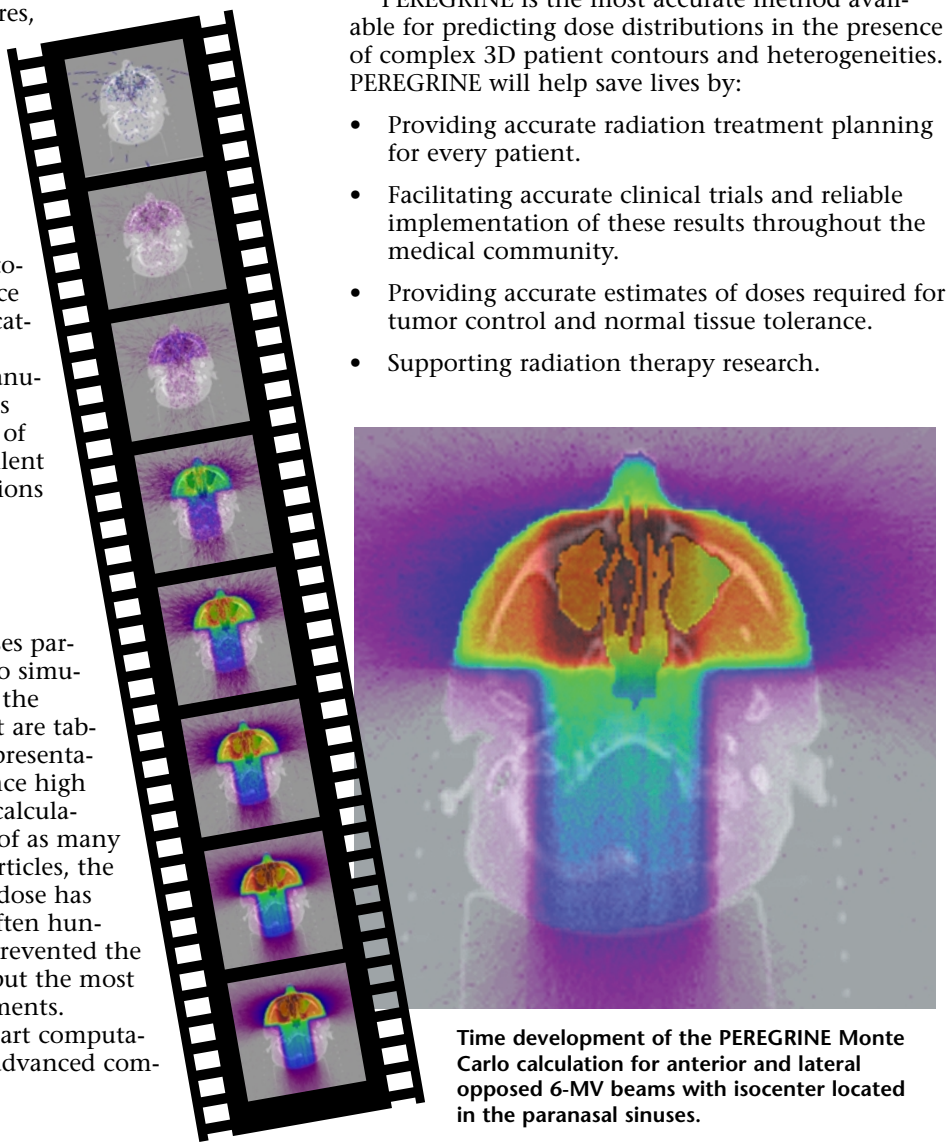
Because Monte Carlo uses particle-by-particle methods to simulate a radiation treatment, the more particle histories that are tabulated, the better is the representation of the actual dose. Since high resolution, high accuracy calculations can require tracking of as many as 100 million incident particles, the time required to calculate dose has been prohibitively long (often hundreds of hours). This has prevented the use of Monte Carlo in all but the most research-oriented environments.

Now, using state-of-the-art computational techniques and an advanced computer architecture, PEREGRINE brings Monte Carlo treatment planning to the desktop. The PEREGRINE Dose Calculation Engine combines the hardware, software, and networking components needed to add this single-unit design to any treatment planning system via a simple network connection, much like a file server in an office.

Advantages

PEREGRINE is the most accurate method available for predicting dose distributions in the presence of complex 3D patient contours and heterogeneities. PEREGRINE will help save lives by:

- Providing accurate radiation treatment planning for every patient.
- Facilitating accurate clinical trials and reliable implementation of these results throughout the medical community.
- Providing accurate estimates of doses required for tumor control and normal tissue tolerance.
- Supporting radiation therapy research.



Time development of the PEREGRINE Monte Carlo calculation for anterior and lateral opposed 6-MV beams with isocenter located in the paranasal sinuses.

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PEREGRINE is a work in progress. The PEREGRINE technology has been licensed to NOMOS Corporation for distribution.

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

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